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Visualization of water behavior in the in-plane and through-plane directions in a PEFC using a neutron image intensifier

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Abstract

Water distributions of a polymer electrolyte fuel cell (PEFC) with 9-parallel channels during operation were visualized using a neutron radiography facility at B4 port in KUR (Kyoto University Research Reactor). An imaging system with a neutron image intensifier (I.I.) was employed for reducing the exposure time, and the water distributions in the in-plane and through-plane directions in the PEFC were alternately obtained every 20 sec. The accumulation processes from the GDL to the channels were confirmed. Water accumulated in the GDL at the cathode and evacuation into the channels started around 5 min. Water tended to accumulate at the edge of the ribs, and accumulated as water drops in the channels. The size of the water drops grew up to 1 mm which was the same size as the channel width and height, and the cell voltage was decreased because the liquid drops disturbed the air supply.

Keywords: Water distribution; Water accumulation; Liquid drops; Paralle channels

1. Introduction

Fuel gas (hydrogen gas) and oxidant gas (air) are supplied to a polymer electrolyte fuel cell (PEFC). Protons pass through the electrolyte membrane, and combine with oxygen to form water in the cathode reaction site. The generated water must be supplied appropriately to the proton exchange membrane (PEM) for proton conduction. It is well known that accumulated water in the gas diffusion layer (GDL)

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prevent the gas diffusion, and it affects the fuel cell performances. Therefore, water management in the PEFC is important, and clarification of the water transport mechanisms between the PEM, GDL and gas channel has been of wide concern. Neutron radiography is a powerful tool for the investigation [1-5]. In this study, water distributions of a PEFC with 9-parallel channels during operation were visualized using a neutron radiography facility. An imaging system with a neutron image intensifier (I.I.) was employed for reducing the exposure time, and the water distributions in the in-plane and through-plane directions in the PEFC were alternately obtained every 20 sec.

2. Experimental apparatus

The neutron radiography facility at B4 port in KUR (Kyoto University Research Reactor) was used in this study. Fig. 1 shows a schematic diagram of the experimental apparatus. A Gadolinium type neutron image intensifier (Ultimage™ n γ type (Gd-Type2), Toshiba Corp.) [6] with a 4 inch view size and a CCD camera (Alta U16, Apogee Inst.) with pixel numbers of 4096 × 4096 and gray scale of 12 bit were used. Pixel size was 6.8 μm/pixel. The exposure time could be reduced to 10 sec using the system. The measurement interval was set at 10 sec, and the cell was rotated 90° using a rotating table during the interval. Hence, water distributions in the in-plane and through-plane directions in the PEFC were alternately obtained every 20 sec. Using pictures which were no-water conditions and filled with water conditions in the channels, image processing was carried out in order to obtain the two-dimensional water distributions. The horizontal L/D was set at 600 using a vertical slit with width of 3 mm.

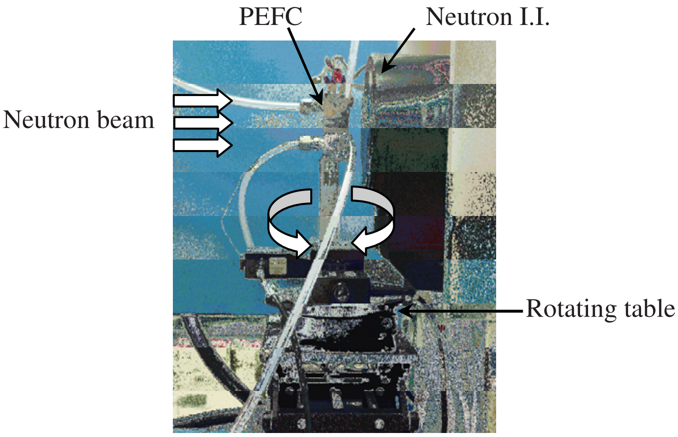

Fig. 1. Schematic diagram of the imaging system

Schematic diagrams of the PEFC are show in Fig. 2. A PEM is sandwiched between GDLs and separators at the anode and the cathode. The PEM was Nafion® NR-212 with thickness of about 90 μm including the catalyst layers. The area was 10 × 19 mm^2. The GDL was carbon paper (TGP-H-060, Toray Ind.) with thickness of 190 μm. The separator has 9-parallel gas channels with equal width and depth of 1 mm. It is expected that the distribution of the current density is different between rib and channel, and it may affect the water generation. Therefore, the authors selected the parallel channels for visualizing the difference of water accumulation process in the GDL by the rib and the channels. Experimental conditions were a current density of 210 mA/cm^2, a hydrogen flow-rate of 28 cc/min (utilization of 10%), and an air flow-rate of 66 cc/min (utilization of 10%) without humidification. The experiment was carried out at room temperature.

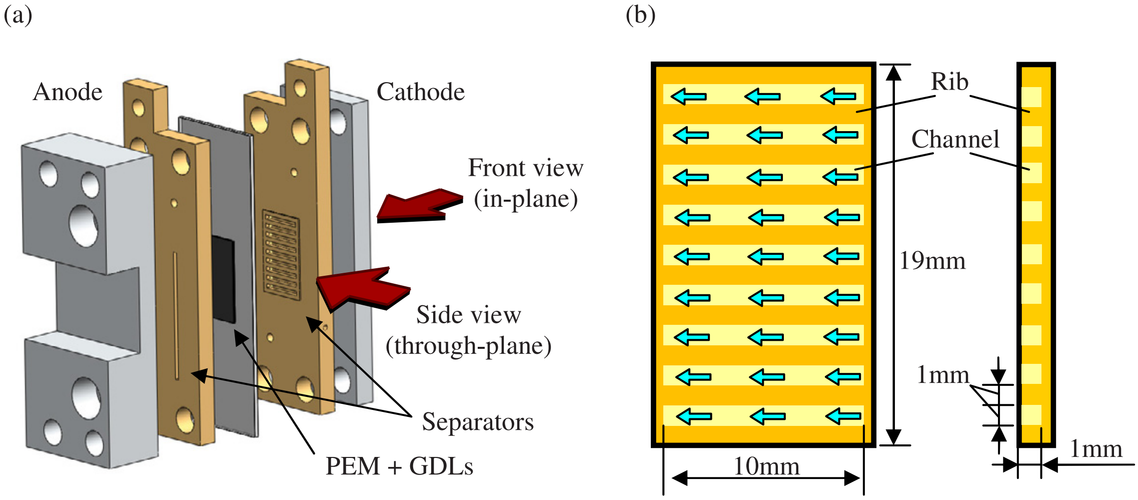

Fig. 2. (a) diagram of the PEFC; (b) geometry of the gas channel

3. Results and discussion

Fig. 3 shows the time-series of the cell voltage. The cell voltage was almost stable until 17 min. It decreased rapidly after that time, and the PEFC stopped around 23 min because of the low voltage.

Two-dimensional water distributions in the in-plane and through-plane directions in the PEFC are shown in Figs. 4. Wide blur is confirmed from the side view. It may be because the I.I. was sensitive to not only neutrons, but also γ rays. However, the water accumulation mechanism can be obtained qualitatively. Water accumulated mainly in the GDL, and little water existed in the channel at the cathode until around 5 min. After that time, water gradually evacuated to the channel. It can be confirmed that water accumulation in the channel tended to be upper and lower positions facing on the GDL as shown in the side view at 12 min. These indicate that water tended to accumulate in the GDL at beginning of the PEFC operation. Water evacuation to the channels started from the near side of the ribs in each channel when the water accumulation in the GDL reached to a certain values. As a result, much water stayed around the rib corner in each channel.

Water accumulation in the channel increased with time, and many liquid water drops are confirmed at 16 min 20 sec. Small liquid drops are around rib corners at the time as shown by red line. The water drops grew up and formed a large drop at 19 min. Many water drops grew up to about 1 mm which was the same size as the channel width and height. As a result, the water drops disturbed the air supply and the cell voltage suddenly decreased.

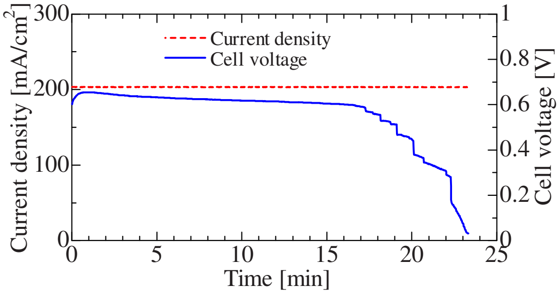

Fig. 3. Time-series of the cell voltage

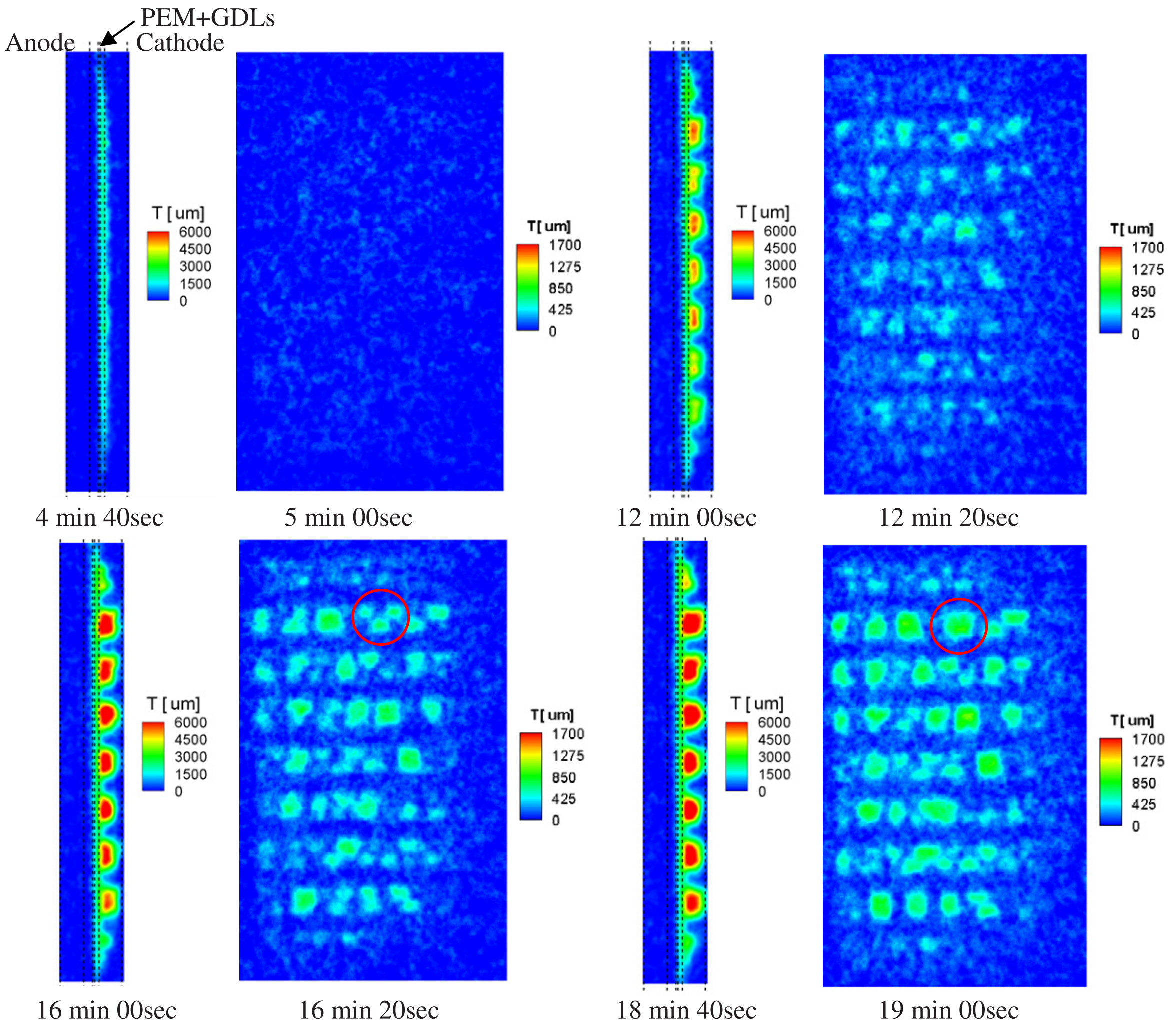

Fig. 4. Water distributions in in-plane and through-plane directions of the PEFC

4. Conclusions

Water distributions in the in-plane and through-plane directions in the PEFC were alternately obtained by using neutron radiography. Water behavior during the PEFC operation, and the accumulation processes from the GDL to the channels were obtained. Water generated in the GDL at the cathode and evacuation into the channels started around 5 min. Water tended to accumulate at the edge of the ribs, and accumulated as water drops in the channels. The size of the water drops grew up to 1 mm which was the same size as the channel width and height. As a result, cell voltage decreased because of disturbance of the air supply by the liquid drops.

Acknowledgements

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